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SUPPLEMENTARY NOTES ON CORE DRILLING IN THE SALT BEDS OF WESTERN TEXAS AND NEW MEXICO: TESTS 13 TO 24

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BY

E. P. HAYES

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SUPPLEMENTARY NOTES ON CORE DRILLING IN THE SALT BEDS OF WESTERN TEXAS AND NEW MEXICO. TESTS 13 TO 24[1]

By E. P. Hayes[2]

INTRODUCTION

This report supplements the date contained in Bureau of Mines Information Circular 6156, "Special features of core drilling in the salt beds of Western Texas and New Mexico," by J. S. Wroth. That circular dealt with the drilling of the first 12 of the 24 potash tests made by the U. S. Bureau of Mines in cooperation with the U. S. Geological Survey; this report is concerned with the drilling of the last 12 tests.

ACKNOWLEDGMENTS

The writer is indebted to R. E. Heithecker, the Bureau of Mines engineer who had charge of the drilling of tests 13 to 17, for his well-prepared records on the drilling of these tests.

PRINCIPAL POTASH MINERALS PRESENT

Three potash minerals have been found in the Permian Basin in important quantities: (1) Polyhalite, a potassium, magnesium, and calcium sulphate ($2CaSO_4.MGSO_4.K_2SO_4.2H_2O$) which is very slowly soluble in water; (2) carnallite, a potassium, magnesium chloride ($KMgCl_3.6H_2O$) which is extremely soluble in water; and (3) sylvite, a potassium chloride (KCl) which is readily soluble, especially in hot water. It is obvious that if polyhalite is present it can always be discerned in well cuttings, while carnallite and sylvite, being more readily soluble in water, would nearly always dissolve in the water used for ordinary drilling.

DRILLING PRACTICES

Specifications.- Contract specifications are set forth in Information Circular 6156, previously referred to.

Equipment.- In addition to the description of equipment given in Information Circular 6156, further points of interest are noted in the following paragraphs.

Aside from requiring the use of a double core barrel, no specifications were made as to the equipment to be used. As it happened two contractors were successful in obtaining all the work. One contractor used steam for power, oil as fuel, a spudder to churn-drill the overburden, and a steam-powered core drill and steam-driven solution pump to core the salts. The other contractor used a gasoline-driven core drill, with fishtail bits to drill the over-

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[1] - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used:
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sharpened every 3 to 5 feet in such material, and in some cases more often. Fishing jobs on a spudder are usually less difficult than on a rotary machine, and less time is required to recover the bit. Fishtailing in caving formations has a decided advantage over the use of the spudder in that the drilling solution may be made heavy with mud, which cements the formations and tends to eliminate the caving. The water used in spudding has a decided tendency to make the formation softer and more apt to cave in and catch the spudding tools. With the use of the fishtail bit, more time is required to go in and come out of the hole, as the rods used must be unscrewed for each trip in and out, while the spudder drilling line winds on the reel without stopping. Three men are required as a crew for fish-tailing, whereas only two men are needed on a spudder rig.

The steel derrick furnishes a stronger structure than the A frame for the handling of casing and tools, more floor space to operate the drill, and being higher, a longer stand of rods can be used, which means a material saving of time in going in and coming out of the hole. The erection time is about the same for both rigs, although initial investment in the steel derrick is higher. A steel derrick may be used with either the spudding rig or with the fishtail rig.

Steam offers more flexible power and cheaper fuel than gasoline, but requires more water and more fuel. These are factors to be seriously considered in regions where water is scarce and where hauling of both water and fuel oil is difficult and expensive. Scale in the boiler must be contended with, and the boiler must be washed and cleaned about once a week to insure safe operation. Gasoline is a more expensive fuel than oil, but less of it is required and it is cheaper where haulage is considered. Gasoline-driven drills have greater maintenance costs than steam outfits, but the writer is of the opinion that in a country such as the Permian Basin, where practically all water contains much gypsum and where water and fuel must be hauled some distance, a gasoline driven rig is more cheaply operated. If a gasoline driven spudder is available, it is more desirable than a fishtail rig to drill the overburden.

Further Notes on Handling of Tests.- Procedure for drilling the overburden was left to the judgment of the contractor's drilling superintendent, and no definite program was laid out by the Bureau of Mines. Inasmuch as the responsibility for putting down the test lay with the superintendent, and the amount of casing used was of no interest to the bureau, he could start as large a hole as he thought necessary in order to get a full 2½-inch salt core, and could use just as much or just as little casing as he deemed wise, provided his casing shut off all water above the salt. The bureau engineer and the survey geologist tried always to give the contractor casing seats above the salt, so that he would not have to cement his last string of casing in the salt.

As a rule the drilling of the various tests proceeded along more or less the same lines. A hole large enough to take a joint of 10-inch casing was started at the surface; then the size of the hole was reduced and drilled to take 8¼-inch casing. The length of 8¼-inch casing varied, as in some tests it was used to shut off only the top water, and in others to shut off all waters above the salt. From the bottom of the 8¼-inch casing to the top of the salt, 6-5/8-inch casing was run, and landed or cemented as required to make a tight joint before starting to core the salt. Usually an attempt was made to find an anhydrite band on which to land this casing, but if this could not be done the casing was cemented in the next

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best formation found. In several cases a tight seat was made by suspending the casing from the collar of the test and cementing it in the salt. Then 5 3/16-inch casing was run, since the 6-5/8-inch casing was too large for the pumps to lift out the cuttings from the hole, while the 5-3/16-inch gave approximately the proper velocity of the solution to clean the hole at a pressure at the bit which was not so high as to cause washing of the core. In case it was necessary to shut off leakage of the drilling solution in the salt, 4½ or 3½ inch flush-joint casing was run or the 5-3/16-inch casing was pulled, the hole reamed, and the 5-3/16-inch casing lowered. The flush-joint casing was too light in weight to be handled without great care and was used only as a last resort.

The drilling solution was made up in a large tank or sump by first saturating water with salt. Before starting the core drilling, the contractor was as a rule allowed to test the tightness of the hole by filling it with this saturated salt solution. No damage was done the salt formation in case the hole was not tight and the salt solution leaked out, and the salt solution which would be lost due to leakage was much cheaper than the solution saturated with salt, magnesium chloride, and potassium chloride. If the hole was found to be tight, 3 pounds of magnesium chloride and a ½ pound of potassium chloride per gallon of saturated salt solution were then added and the solution was circulated through the hole for several hours. In this way the solution was thoroughly mixed and the solution originally used in the hole for testing was saturated with the other two chloride salts. With the addition of the magnesium chloride, some of the sodium chloride was precipitated and with the addition of potassium chloride, both sodium and magnesium chloride were precipitated to some extent. A sump placed in the return line or ditch between the drill hole and solution supply sump collected the cuttings and some of the surplus salts, though most of the precipitated salts were thrown out in the supply sump. As the hole was deepened and more solution became necessary, saturated solution was added in small quantities from a reserve supply tank. In the event that solution was lost for any reason whatever, the hole was cemented as outlined in a following paragraph, and new solution was made up and circulated as if the core drilling had just started.

Cementing in the salt to shut off leakage was successful if properly done. Too often, however, it was attempted without following the proper procedure. The following method has been found to be successful. The hole is bailed dry to a point below where the cement is to be placed, and a wooden plug fitting the hole tightly is set just below the point where the shut-off is desired. The cement is mixed in a box in the proportions of 5 gallons of water to one sack of cement, and an accelerator is added just before the mixture is run into the hole. The cement can either be poured through the rods, pumped in with the solution pump, or placed with a bailer. If rods are used care must be taken to see that they are not left in the cement long enough to become set in the cement. A second plug is run on to the top of the cement, a weight is placed on it to force the cement out into the crevice or point of leakage, and the hole is filled with water to hold the plug in place. After the cement is thoroughly set, the plug is drilled out and the hole tested to see that it is tight.

The amount of core cut during a shift depends upon the character of the formation and the skill of the driller. The driller was responsible for his shift, and was in charge of the operations, subject to orders from the drilling superintendent or tool pusher.

As a rule the weight of the rods and core barrel was sufficient for cutting any salt formation, sylvite, carnallite, clay, shale, or other soft formations. To cut the polyhalite or anhydrite, it was generally necessary to use the hydraulic feed to force the bit through these formations.

The use of diamonds was specified for core drilling in salt formations. Bit wear of diamonds was small, since very little abrasive material was encountered after the overburden was drilled, but diamonds had a tendency to tear the core, especially if they were well

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rounded and well suited for drilling in harder rock. A set of well-rounded stones, specially selected from a large stock of excellent rock-cutting diamonds, was found to cut a very poor core. If new diamonds were used and set with the sharp, unworn edges out, they cut a good core but had a tendency to chip. Bortz was used successfully when set with the sharp edges out, and had an advantage over ordinary black diamonds in being less expensive; in the event that the bit was stuck or lost in the hole and could not be recovered, less money was lost. Bits made up with stellite teeth, or with teeth of similar especially hard alloy, were found to cut a more satisfactory core with less tearing than the diamonds. Two types of bits were made up and both proved to be satisfactory if the teeth were kept sharpened. The first bit was made by building up, with a welding torch, triangular-shaped teeth onto a regular bit blank. Twelve teeth were used, in four sets of three teeth each, the teeth being narrower than the face of the bit and staggered to allow free passage of solution at the cutting point. Each alternate tooth had a wing on the side of the bit to insure ample clearance between the bit and the side of the hole. The bit was set up in a lathe and was ground to gage both inside and outside with an emery wheel. The face of each tooth was then ground so that the cutting edge extended completely across the face of the tooth. The second type was made by setting sharpened stellite inserts in a regular bit in the same manner as diamonds are set in the bit. Both types should be set with an edge out and either changed when dulled or reground to keep sharp and to gage.

Most of the poor core was caused by etching or washing, between which it was difficult to distinguish; etching was due to an unsaturated drilling solution which dissolved the core, and washing to too high a solution pressure at the drill bit which caused a high velocity of the solution and wearing away of the salt. Etching usually showed in the sylvite or carnallite bands as a leaching out of spots in the core, while washing showed as vertical runs along the length of the core. In neither case was the core lost, but a fair determination of the potash in the core could not be made if any appreciable portion of the surface was etched or washed away.

Losses of core were due to several causes. The core barrel held 15 feet of core when full, and was usually pulled when it contained 13½ to 14 feet of core. If a driller took more than 15 feet of core, he ground up some of it to get it all in the barrel. If the core became blocked (that is, jammed or stuck in the inner barrel) some of it was bound to be ground up unless the driller pulled the core-barrel at once. In either case, some of the core was lost. Sometimes when the barrel was pulled, the core did not break exactly at the bottom of the hole and a stub of core was left. The length of the stub has been as much as 4 feet. If the driller was aware that the stub had been left and was careful in going back in the hole, he could set the barrel over the stub and pick it up with the next barrelful; otherwise it was crushed and lost. Practically all core losses were due to carelessness, though there were some extremely soft formations that washed away rather than cored.

If there was no loss of core, the length of the core as cut was always longer than the depth of the hole because the core broke at the edges of the various formations. It could not be fitted together as it was in the hole, and gave an overage. The driller got no credit for overage of core, but was charged with all losses. The overage was absorbed in the report made by the bureau engineer when he measured the core each week. Inasmuch as the contractor got a bonus for core recovered, it was to his advantage to bring up all the core possible. After the core was measured, the box was nailed or locked and was hauled to the Bureau of Mines core house in town, where it was held to be turned over to the survey's geologist for a careful geological logging and the cutting of the economic portions. These portions were sent to Washington for chemical analysis and final report by the U. S. Geological Survey.

The following tables give a complete record of operations at each well, including contract costs and average figures, for Wells 13 to 24, inclusive.

Performance on the Last 12 Tests

Well No.	Location County	Location State	Total depth Feet	Total depth Inches	Footage drilled in overburden Feet	Footage drilled in overburden Inches	Footage drilled in salts: Footage Feet	Footage Inches	Core-recovery Feet	Core-recovery Inches	Core-recovery, per cent
13	Eddy	N. Mex.	2,139	0	850	0	1,289	0	1,281	3	99.4
14	Lea	do.	[1]2,027	6	[1]1,179	6	848	0	822	0	96.9
15	Eddy	do.	1,079	6	514	0	565	6	565	6	100.0
16[2]	Chaves	do.	514	0	361	6	152	6	152	6	100.0
17	Lea	do.	[3]2,825	0	[3]1,565	0	1,260	0	1,260	0	100.0
18	Loving	Texas	1,876	0	1,205	0	671	0	669	0	99.7
19	Lea	N. Mex.	2,011	6	1,243	0	768	6	767	2	99.8
20	Lea	do.	2,302	4	1,325	0	977	4	977	4	100.0
21[4]	Lea	do.	3,010	0	2,079	0	931	0	925	0	99.4
22	Eddy	do.	1,724	0	606	0	1,118	0	1,103	0	98.6
23	Eddy	do.	904	0	495	0	409	0	406	0	99.3
24	Grand	Utah	1,731	0	1,178	0	553	0	540	6	97.7
Totals			[5]22,143	10	[5]12,601	0	9,542	10	9,469	3	99.2

1 - Test 14 was originally an oil and gas structure test drilled by the Humble Oil & Refining Co., it was taken over at 1,179 feet 6 inches and cored from that point.

2 - Shallowest test drilled by the Bureau of Mines.

3 - Test 17 was an oil and gas test drilled by the Empire Gas & Fuel Co.; it was plugged back to 1,540 feet, a deflector set in the hole, and cored from 1,565 feet where a full-sized core was first obtained.

4 - Deepest test drilled by the Bureau of Mines.

5 - Overburden of tests 14 and 17 included in this figure.

Casing Record and Contract Costs for Churn and Core Drilling, Wells 13 to 24

Well No.	Casing record: Set Feet	Set Inches	Recovered Feet	Recovered Inches	Contract Costs, Churn drilling: Total	Per foot
13	1,514	0	740	0	$4,887.50	$5.75
14	2,050	0	138	3	[1]2,398.51	2.03
15	897	0	897	0	2,955.50	5.75
16	252	0	212	0	2,078.63	5.75
17	4,588	0	3,038	9	[2]2,896.20	1.85

1 - Structure test taken over from Humble Oil & Refining Co. at 1,179 feet 6 inches. This amount represents amount paid drilling contractor for casing which was not recovered.

2 - Test was taken over from Empire Gas & Fuel Co. and plugged back to about 1,540 feet. A deflector was set and coring started. At 1,565 feet the first full-sized core was obtained. This amount represents the cost of deflecting the hole ($1,500) and the amount paid the Empire Co. for casing left in the hole ($1396.20).

Casing Record and Contract Costs for Churn and Core Drilling, Wells 13 to 24 - Continued

Well	Casing record				Contract Costs	
	Set		Recovered		Churn drilling	
No.	Feet	Inches	Feet	Inches	Total	Per foot
18	2,702	0	1,902	0	7,230.00	6.00
19	2,995	11	2,907	7	6,090.70	4.90
20	2,992	0	2,488	0	6,492.50	4.90
21	No record				12,370.05	5.95
22	860	6	716	6	3,605.70	5.95
23	726	0	475	0	2,945.25	5.95
24	1,202	5	101	0	7,009.10	5.95
Totals	20,779	10	13,616	1	60,959.64	4.84

Casing Record and Contract Costs for Churn and Core Drilling, Wells 13 to 24 - Continued

Well	Contract Costs					
	Core drilling				Total Churn & core	Per foot of total depth
No.	Drilling	Core recovery	Total	Per foot	drilling	
13	$10,956.50	$1,281.25	$12,237.75	$9.49	$17,125.25	$8.01
14	7,208.00	822.00	8,030.00	9.47	10,428.51	5.14
15	4,806.75	565.50	5,372.25	9.50	8,327.75	7.71
16	1,296.25	152.50	1,448.75	9.50	3,527.38	6.86
17	11,970.00	2,520.00	14,490.00	11.50	17,386.20	6.15
18	6,374.50	1,338.00	7,712.50	11.49	14,942.50	7.96
19	5,917.45	1,534.32	7,451.77	9.70	13,542.47	6.73
20	7,525.44	1,954.67	9,480.11	9.70	15,972.61	6.94
21	9,310.00	1,850.00	11,160.00	11.99	23,530.05	7.82
22	11,181.00	2,206.00	13,387.00	11.97	16,992.70	9.86
23	4,090.00	812.00	4,902.00	11.99	7,847.25	8.68
24	5,530.00	1,081.00	6,611.00	11.95	13,620.10	7.87
Totals	86,165.89	16,117.24	102,283.13	10.72	163,240.77	7.37

Distribution of Time Consumed in Sinking Wells 13 to 24

Well No.	Total days on site	Moving in, setting up, plugging etc., days	Available for drilling		Actual drilling time		Miscellaneous delays	
			Days	Per cent	Days	Per cent	Days	Per cent
13	82	41	41	100	26.8	65.4	14.2	34.6
14	63	36	27	100	13.9	51.5	13.1	48.5
15	37.2	[1]17	20.2	100	10.5	52.0	9.7	48.0
16	22.7	10	12.7	100	6.4	50.4	6.3	49.6
17	62.4	[2]33	29.4	100	21.2	72.1	8.2	27.9
18	110.3	14	[3]96.3	100	31	32.2	[3]65.3	67.8
19	115.3	[4]38	[5]77.3	100	30.9	40	[5]46.4	60
20	88	[6]40	48	100	35.9	74.8	12.1	25.2
21	82	[7]26	56	100	42.7	76.3	13.3	23.7
22	55.1	22	33.1	100	22.2	67.1	10.9	32.9
23	27	11	[8]16	100	11.2	70	4.8	30
24	96.2	[9]12	[10]84.2	100	24	28.5	60.2	71.5
Totals	841.2	300	541.2	100	276.7	51.1	264.5	48.9

1 - Includes 6 holidays.

2 - Includes 6 days on deflecting job and 6 days waiting for deflector cement to set.

3 - Includes 9.3 days when no night crew was used and 39.6 days spent in fishing for diamond bit.

4 - Includes 13 Sundays that crews did not work.

5 - Includes 32.3 days spent in fishing for core bit.

6 - Includes 14 Sundays and holidays that crews did not work, also 7 days making water well for rancher.

7 - Includes 10 days taken by trucking contractor to move rig from Utah.

8 - Includes 3.3 days when night crew was not used.

9 - Does not include time used to truck equipment to Utah.

10- Includes time lost waiting for 9 cementing jobs to set (12 days); 2 days that crews did not work waiting for water; 5 days that crews did not work waiting for chloride; 20 days delay while attempting to cement with salt solution in hole; and 2 days during which well was shut down while solution was being made up to saturation point.

Data on Churn Drilling

Well			Total	Actual drilling time		Footage per day of—	
No.	Date started	Date finished	time, days	Days	Per cent	Total time	Drilling time
13	July 23, 1929	August 8, 1929	16	11.7	73.1	53.1	72.6
14	No churn drilling		None	None	-	-	-
15	December 2, 1929	December 13, 1929	11	6.7	60.9	46.7	76.7
16	January 8, 1930	January 19, 1930	10.3	4.7	45.6	35.1	76.9
17	No churn drilling		None	None	-	-	-
18	May 29, 1930	July 9, 1930	40.5	19.5	48.2	29.8	61.8
19	July 24, 1930	August 16, 1930	[1]20.	14.9	74.5	62.1	83.4
20	November 20, 1930	December 23, 1930	[2]28.	18.7	66.8	47.3	70.8
21	September 11, 1931	October 15, 1931	34	24	70.6	61.1	86.6
22	May 28, 1931	June 14, 1931	16.1	8.8	54.7	37.6	68.9
23	May 13, 1931	May 24, 1931	11	6.2	56.4	45.0	79.8
24	July 28, 1931	September 4, 1931	38.4	15.7	40.9	30.7	75.0
		Totals	225.3	130.9	58.1	[3]43.7	[3]75.3

1 - Three Sundays are not included.

2 - Five Sundays are not included.

3 - Does not include footage on tests 14 and 17.

Data on Core Drilling

Well			Total	Actual drilling time		Footage per day of—	
No.	Date started	Date finished	time, days	Days	Per cent	Total time	Drilling time
13	October 18, 1929	November 12, 1929	25	15.1	60.4	51.6	85.4
14	August 28, 1929	September 24, 1929	27	13.9	51.5	31.4	61.0
15	December 13, 1929	December 22, 1929	9.2	3.8	41.3	61.5	148.8
16	January 19, 1930	January 21, 1930	2.4	1.7	70.8	63.5	89.7
17	April 18, 1930	May 17, 1930	29.4	21.2	72.1	42.8	59.4
18	July 10, 1930	September 14, 1930	[1]55.8	11.5	20.6	12.0	58.3
19	August 21, 1930	October 28, 1930	[2]57.3	16	27.9	13.4	48.0
20	January 4, 1931	January 28, 1931	[3]20	17.2	86	48.9	56.8
21	November 11, 1931	December 3, 1931	22	18.7	85	42.3	49.8
22	June 20, 1931	July 10, 1931	[4]17	13.4	78.8	65.8	83.4
23	May 25, 1931	May 30, 1931	5	5	100	81.8	81.8
24	September 4, 1931	November 21, 1931	45.8	8.3	18.1	12.1	66.6
		Totals	315.9	145.8	46.1	30.2	65.4

1 - Includes 39.6 days spent in fishing for diamond bit.

2 - Ten Sundays are not included, but 32.3 days spent in fishing for diamond bit are included.

3 - Four holidays are not included.

4 - Three holidays are not included.

DRILLING NOTES ON INDIVIDUAL TESTS

Test 13.- Moving into the site covered eight days, a major part of which time was spent in building bridges and roads. Two days were spent in fishing for a bailer that was lost in the hole, but aside from that the spudding was done without delay. A gas pocket encountered while coring at 932 feet blew the solution from the hole. The gas soon exhausted itself, and it was not necessary to cement, although at a lower depth the solution was lost in a crevice and two cementing jobs were done before circulation was regained.

Plugging and dismantling consumed 13 days. The 6-5/8-inch casing was shot at various depths and attempts were made to pull it. It finally came loose at the top joint, the tightness probably being due to cavings holding the casing rather than cement.

Test 14.- A new drilling machine was sent in to core this test. Twenty-one days were required to rig up, as a number of parts had not been sent from the factory and had to be sent out later. Delays in drilling were accounted for mainly by one driller's being ill and losing 10 shifts of eight hours, and 4 idle days were caused by having to wait for fishing tools. Waiting for the cement to set on the first string of casing caused the balance of the delay.

Ten days were taken to plug the test and to dismantle the rig, practically all of which was due to trouble in pulling the casing. Only 160 feet of 2,050 feet of casing was recovered. This hole had been taken over from the Humble Oil & Refining Co. after they had completed a structure test to 1,181 feet and 6 inches. Government paid the Humble Co. contractor for the casing left in the hole. This amount ($2,398.51) represents the cost of drilling the overburden.

Test 15.- The 6-5/8-inch casing was set at 282 feet and the hole cored from 282 feet to 467 feet. The hole was then reamed to 513 feet and the 5-3/16-inch casing landed. Coring was resumed to 611 feet. At this point the solution was lost; so the 5-3/16-inch casing was pulled, the hole reamed to 611 feet 6 inches, and the 5-3/16-inch casing rerun. A day was lost when an air or gas pocket was drilled into at 603 feet, and drilling had to stop until the gas was exhausted.

No casing was lost, as the casing was not cemented and was easily pulled.

Test 16.- This test was drilled from top to bottom with the coring machine, a fishtail bit being used on the overburden and a core bit on the salt. Delay in drilling the overburden was accounted for by a 3-day wait for the cement to set in a crack at 344 feet, and a 2-day delay occasioned by extremely cold weather which froze the pumps. No night shift was used during the coring and there were no other delays.

Test 17.- Well 17 was originally drilled by the Empire Gas & Fuel Co. as an oil and gas test, was plugged back above the salt, a steel deflector cemented in the hole, and coring started. The deflector was especially made for the job and was set at 1,540 feet in the 6-5/8-inch casing with 20 sacks of cement. Coring was then started, the bit drilling through the side of the 6-5/8-inch casing and a full core being taken at 1,565 feet. Six days were required to set the deflector and an additional six days for the cement to set thoroughly.

Trouble was experienced in recovering the casing, and nearly all of it was left in the test. Eleven days were taken to plug the test and dismantle the rig. The Government paid $1,500 for the deflecting job and $1,396.20 for the casing left by the oil company in the test. This total ($2,896.20) is the amount that is chargeable to the drilling of the overburden.

Test 18.- Of the delays on drilling the overburden, about 10 days are chargeable to the fact that no night crew was used. A large part of the overburden was sandstone which wore out the fishtail bits after from 6 inches to 2 feet of drilling. The bits were faced with stellite, but though it was better than steel, the sandstone wore it very quickly. Over

$1,500 was spent by the contractor for building up the stellite fishtail bits.

At 1,295 feet a diamond bit was twisted off the core barrel and remained in the hole when the driller started coring before he had proper solution circulation. The 5-3/16-inch casing had been dropped and the last joint badly bent so that no fishing tools could pass through the casing. When an attempt was made to pull the casing, it parted and left five joints in the hole. These five joints were drilled up with a special steel cutting bit and the diamond bit finally recovered. Nearly 40 days were lost in fishing for the bit and in clearing the hole of the steel chips which had dropped in while the casing was being drilled up.

Test 19.- No difficulties were encountered in cutting the overburden which was drilled with a spudding machine. Coring was started at 1,243 feet. At 1,306 feet the diamond bit became wedged in the hole in a dolomitic formation and the bit was twisted off. Left-hand rods were obtained from the factory and the drilling rods were backed off the core barrel, together with the water head and inner core barrel. A special reamer was then made and the outer core barrel was drilled up. A chip box was used on the reamer and all the steel chips were recovered from the hole. The chips were weighed and found to be within 2 ounces of the weight of the outer core barrel when new. When the outer core barrel had been cut to the diamond bit and the hole washed for 24 hours with salt solution, the bit was caught on a taper tap and taken from the hole. Thirty-two days were lost in waiting for the left-hand rods and in fishing for the bit.

Twelve days were used in plugging test and dismantling rig. The rig was moved to the next location as it was dismantled. A sandy trail caused the work to proceed slowly. Very little casing was lost, as only the 5-3/16-inch was cemented.

Test 20.- No trouble was met with in drilling the overburden. At 1,125 feet a band of salt was found and without waiting for approval, the contractor started to tear down his spudder and erect his core drill. When he found that some dolomitic formations were still to be drilled and that he was apt to stick his diamond bit again, he tore down the core drill and erected his spudder to drill about 200 feet more. About five days were lost on this account.

The contractor needed additional casing to finish the hole and ran a string of extremely light 3-3/4 inch, some of which was lost when he pulled the casing. An extra seven days were consumed when the completed test was converted to a water well for a rancher.

Test 21.- The drilling of the overburden was done on subcontract by a local well-drilling contractor, who started too small a hole in order to save a string of casing. At 1,076 feet a quicksand was struck, and although the contractor tried for two months he was not able to drill deeper. As he was short a string of casing, he could not case off the quicksand and finally had to abandon the hole. A new subcontractor who had had experience in the locality drilled the overburden with very little delay, and any that occurred was due to mechanical troubles. Coring was completed without serious delay.

Test 22.- The overburden drilling was done by a subcontractor, and no record was kept by him of any special features. Some trouble was met on account of lack of water because of the extreme drought at the time and the subcontractor was required to haul his water from considerable distances.

Two days were spent in covering the trails with bear grass in order that the trucks hauling the coring machine could pass over them to reach the location. Three days were lost when the crews took time off around the Fourth of July.

As the coring machine was sent to U ah to drill test 24, eight days were taken to plug the test, dismantle the rig, and load the equipment on trucks.

Test 23.- The overburden was drilled with the coring machine, using a fishtail bit. No night crew was used and three days delay was charged to the total time available for drilling

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on that account. Two gas pockets blew the solutions from the hole at different times but no time was lost.

Test 24.- Test 24 was drilled in Utah; it was the only test drilled outside of Texas or New Mexico and at a considerable distance from the base of supplies. The overburden was sandstone, badly broken, and very close to a fault. Rock bits solved the drilling, but crevices required nine cementing jobs, which caused a total delay of 12 days. Water had to be obtained from a seep, and four days were lost while the crews waited for enough water to flow into the seep so that they could have enough to drill continuously.

Coring was started at 1,178 feet. At 1,206 feet, a leak in the formation developed and an attempt was made to cement without bailing the salt water from the hole. Later a second attempt was made at the same point without success. Finally the hole was bailed, a plug set below the leak, the cement run in through the rods, and a second plug set on the cement. After three days the plug was drilled out and the test completed without any further difficulty. Twenty days were lost on these three cementing jobs that could have been saved. Seven days were lost on account of not having enough magnesium chloride on hand, and having to wait while trucks brought 12 tons from the contractor's warehouse at Carlsbad, N. Mex. The equipment was then trucked to New Mexico and the twenty-first test was cored. This completed the work.